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# Microfossil-determined provenance of clay building materials at Burrough Hill Iron Age hill fort, Leicestershire, England

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## ABSTRACT

The Iron Age hill fort at Burrough Hill, Leicestershire, eastern England, lies in a lowland landscape of Mesozoic sedimentary rocks comprising mudstones with thin limestone units, sandstones and ironstones, which are blanketed by Pleistocene till. During the late Iron Age the hill fort was an important central place; permanent occupation probably began in Early–Middle Iron Age and continued into the Roman period. A variety of materials in archaeological contexts from the site, including clay rampart bonding and the clay linings of storage pits and floors, are found to yield characteristically mixed microfossil assemblages of Early to Late Jurassic ostracods and foraminifera, together with foraminifera from the Late Cretaceous. These provide a unique microfossil signature that indicate provenance from the local till. Microfossils can also be recovered from Middle to Late Iron Age potsherds at Burrough Hill, and these too suggest a local glacial source for the clay. Our analysis demonstrates the power of microfossils to provenance clay materials used for construction and manufactures at an Iron Age site, where a detailed baseline understanding of the local geology is firmly established.

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## 1. Introduction

Microfossils can be recovered from a wide variety of sedimentary rocks including limestone, sandstones and mudstones, and are commonly used by geologists to determine the relative ages of rocks (Armstrong and Brasier, 2005), a process based on the principle that all microfossil species have a distinct temporal range. Coupled with the knowledge of the spatial distribution of particular rock strata, microfossils can then be used to determine the provenance of sedimentary rock materials in archaeological and historical materials (e.g. Perch-Nielsen, 1972; Horrocks and Best, 2004; Quinn and Day, 2007; Wilkinson et al., 2008, 2010, 2013; Tasker et al., 2011, 2013). Microfossils are especially useful in this context because of their abundance in small samples, and they have particular value in landscapes where the underlying rock strata are lithologically uniform over wide areas, but that are characterized by stratigraphically distinctive fossils.

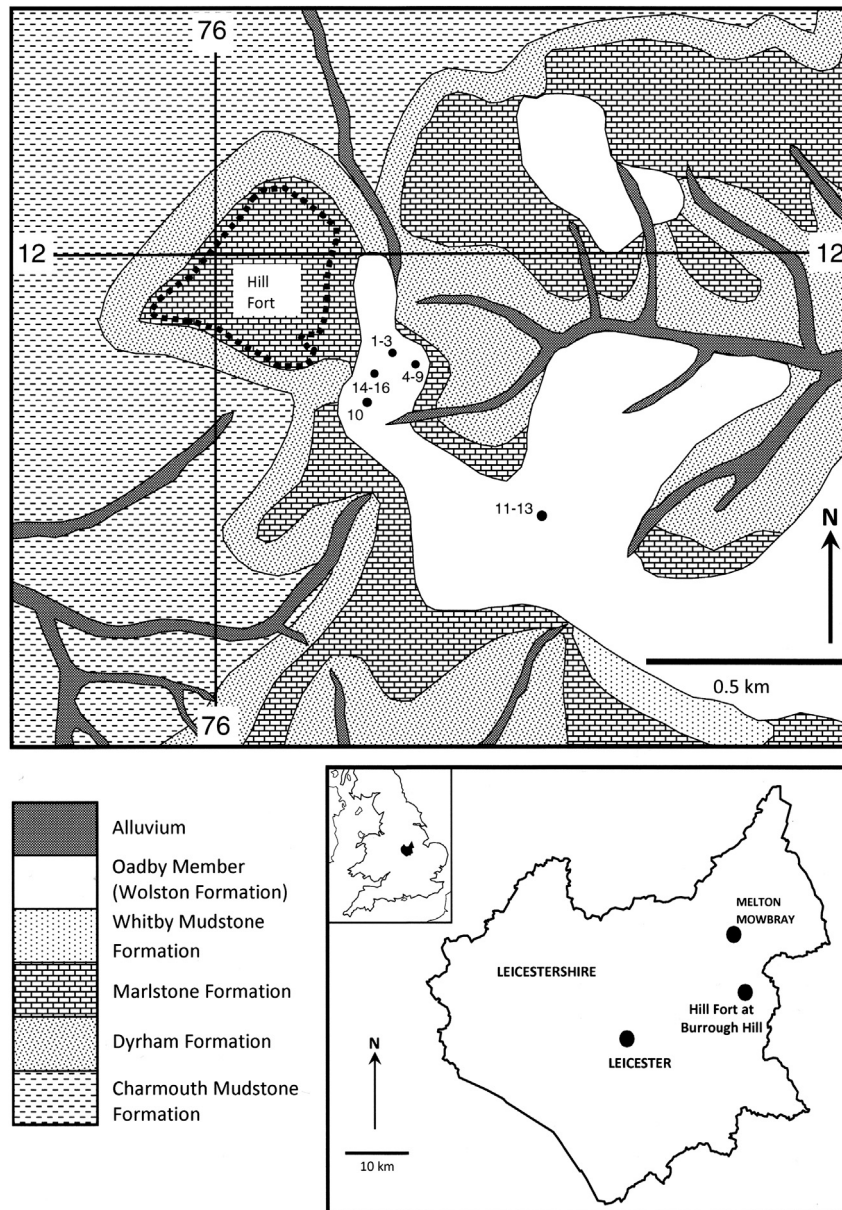
Here we use microfossils to analyze the provenance of clays used in construction at Burrough Hill Iron Age hill fort, East Leicestershire. We also use our microfossil database to make a provisional assessment of microfossils in the pottery at the site. Burrough Hill lies in a lowland landscape of Mesozoic sedimentary rock deposits, mainly mudstones and limestone, covered with Pleistocene glacial deposits. The hill fort occupies a geographically central site in Britain, and during the Late Iron Age was a major centre for the local population. Archaeological materials that are made of clay at the hill fort include pottery and clay linings of walls, floors and storage pits. Microfossils have been recovered from all of these materials and, coupled with a detailed study of the local and regional geology, provide a robust indication of the sourcing of materials for pottery and building at the site.

## 2. Archaeological setting

Burrough Hill is a large univallate (single walled) Iron Age hill fort located approximately 7 km south of the town of Melton Mowbray in Leicestershire (Fig. 1). It is the finest surviving example of a hill fort in Leicestershire and is defined by a trapezoidal

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**Fig. 1.** Geographical and geological context of the Iron Age hill fort at Burrough Hill, Leicestershire, UK: the underlying bedrock geology is of Early Jurassic age, with Pleistocene deposits of Anglian age lying to the immediate east of the hill fort. These latter deposits are the likely source of construction materials within the hill fort and may also have been used as a source of clay for Iron Age pottery at the site. Map redrawn from [British Geological Survey \(2007\)](#).

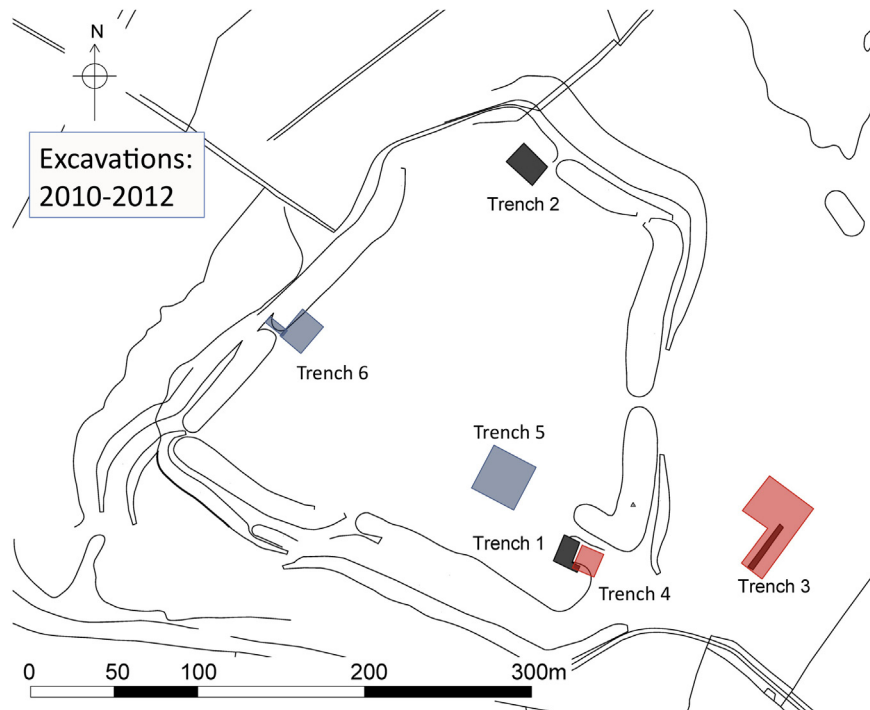
rampart of stone, clay and turf, standing up to 3 m high internally that encloses an area of around 5 ha (Figs. 2 and 3).

Burrough Hill has attracted the interest of antiquarians and archaeologists since the 16th century and during the twentieth century saw successive small-scale excavations in 1935, 1960, 1967 and 1970–71. This work attested to occupation on the site from the Neolithic through to the 4th century AD, but apart from some short notes it remained unpublished and so added little to our knowledge of the site's role (Taylor et al., 2012, p. 49). In the intervening years the significance of this caveat became all the more apparent as developer funded archaeology since the 1990s has transformed our understanding of other features of the later prehistoric landscapes of the East Midlands (cf. Willis, 2006). Although hill forts are iconic monuments of the Iron Age, their distribution is uneven through

the UK. Burrough Hill is one of only a few in the East Midlands, and in the absence of recent research and excavation our understanding of their significance remains poor.

Partly in order to address this problem, the University of Leicester established a 5-year research and training project at Burrough Hill in 2010. The initial large-scale geophysical survey of the site was followed by an excavation programme that has so far systematically sampled several areas of the hill fort including the main gateway into the fort, the ramparts and both intra and extramural settlement (Fig. 2). Excavations in 2010 (trench 1) and 2011 (trench 4) investigated the main SE entrance into the hill fort marked today by monumental in-turned banks that create a passageway ca 40 m long. Trenches 1 and 4 were positioned over the southern side of this entrance passageway in order to





**Fig. 2.** Position of trenches within and adjacent to the hill fort excavated between 2010 and 2012. Microfossil-bearing clay materials documented here are from trenches 3 to 6 (see Table 1).



**Fig. 3.** Aerial view of the hill fort at Burrough Hill taken from the northeast: for orientation with Fig. 2, the main entrance to the hill fort in the southeast corner of the construction is to the top left in the photograph.

investigate its construction, use and abandonment. On excavation the passageway ‘bank’ proved to have originally been a massive stone and earthen rampart between 6 and 8 m thick and probably ca 3–4 m high (Fig. 4). The external faces of the rampart were

constructed with near vertical dry stone walls whilst its core was built using alternate layers of clay and limestone, the latter quarried from a huge external ditch dug through the local Lower Jurassic Marlstone Rock Formation that crops out beneath the hill (Fig. 1).



Fig. 4. View of trench 4 under excavation showing the stone rampart and transverse ribs of large stone blocks running across it.

Close inspection of the ramparts failed to identify any evidence for a timber framework reinforcing or stabilizing the mass of the rampart and preventing its collapse. Instead, this seems to have been achieved through the use of transverse ribs of massive stone boulders that were bedded on a thick blue/grey clay-bonding layer at the foot of the rampart (Fig. 4). The body of the rampart was then built up by filling the ‘bays’ between the ribs with further smaller boulders consolidated with pockets of similar blue/grey clay in layers throughout the rubble core.

The northern face of the rampart formed the southern side of the entrance passageway, the floor of which was covered with a cobbled road surface. In its final phase of construction the in-turned rampart had been lengthened and widened to accommodate the creation of an integral chamber or recess facing out on to the entrance road. This room revealed a complex sequence of occupation with several superimposed layers of Iron Age beaten earth and clay floors with hearths. Analysis of the material culture from the entrance and chamber as well as a series of radiocarbon dates have established that the in-turned entrance and chamber were constructed and in use between *ca* 370–170 BC.

In 2011 excavation also focused on an area of previously unsuspected extramural settlement to the east of the hill fort (Fig. 2, Trench 3). This settlement, first identified by the geophysical survey in 2010, proved to lie within its own ditched annexe and is dated broadly to the 4th–1st centuries BC, contemporary with the main occupation of the interior of the hill fort.

The current project has also seen sample excavation of intramural occupation in several different locations across the site (Fig. 2, trenches 2, 5, 6 and 7). Excavation in 2012 focused on two locations; trench 5 investigated a cluster of large pits identified by the geophysical survey a short distance to the west of the main entrance, whilst trench 6 concentrated on the excavation of a roundhouse and further pits lying in the lee of the western rampart. In trench 5 the rich assemblage of material recovered shows that the pits were used for a variety of purposes from grain storage and the deposition of rubbish to the more deliberate placement of ritual deposits including disarticulated human remains. This activity took place through the mid–late Iron Age (4th–1st centuries BC) and on in to the late 1st century AD, confirming continued occupation of parts of the hill fort after the Roman conquest. The data from trench 6 (Fig. 5) also suggests occupation from the 4th–1st century BC in

the form of a substantial timber built roundhouse and associated pits, some located within an annexe attached to the rear of the building. The pits showed a similar variety of uses to those in trench 5 but also consisted of shallow clay lined features probably designed to hold water for consumption, for use in cooking or for industrial activities such as metalworking. The clay lining of these features and the sides of some of the larger storage pits in trenches 5 and 6 is a distinctive feature of the site showing clear evidence for the deliberate extraction, processing and use of clays as a building material during the Iron Age at Burrough Hill.

In all areas of the site so far excavated the use of clay as a building material in the rampart, for the lining of features cut into the underlying bedrock, for the creation of oven furniture and for the manufacture of ceramics were ubiquitous. As such it was clear that clay was an important resource for the Iron Age communities at Burrough Hill and its likely origin is of interest to understanding life in the hill fort and the relationship of its inhabitants with the surrounding landscape.

### 3. Geological setting

Lower Jurassic deposits from the region around the hill fort are essentially poorly exposed mudstones dipping gently to the southeast, with thin, indurated beds forming topographical features. One of these, the Marlstone Rock Formation consists of hard sandy, shelly limestone (Carney and Ambrose, 2007; Carney et al., 2009). It is relatively resistant to erosion and produces a ‘shelf’ in the landscape on which the hill fort sits (Fig. 3). To the west, the fort overlooks the lowlands of the progressively older Dyrham, Charmouth Mudstone and Blue Lias formations (Fig. 1). To the east of the fort, and overlying the Marlstone Rock Formation, the Whitby Mudstone Formation forms a broad outcrop below the Middle Jurassic Northampton Sand and Lincolnshire Limestone formations that lie some 10–12 km east of the fort. Each of these formations has a characteristic complement of microfossils in eastern England (e.g. Bate, 2009; Bate and Coleman, 1975; Lord, 1978; Copestake and Johnson, 1981, 1989; Boomer and Ainsworth, 2009).

The whole region around the hill fort is covered by Pleistocene (Anglian age) glacial deposits of the Oadby Till Member, Wolston Formation, which is widespread over much of the area to the east of the hill fort (Fig. 1). Regionally this till extends from Nottingham





Fig. 5. View of trench 6 under excavation with the roundhouse and associated pits, many of which were lined with the sampled clays.

and Derby as far south as Moreton-in-Marsh and west to Stratford-upon-Avon (Brenchley and Rawson, 2006). The till is lithologically heterogeneous, depending on the local underlying geology and the path of the Anglian ice sheet. Carboniferous, Triassic and Jurassic lithologies are found within the till (Scheib et al., 2011), and below a depth of about 0.5 m Cretaceous chalk and flint fragments (Ambrose, 2006).

#### 4. Methodology

In order to assess the likely sources of materials used for building and ceramics at the hill fort we have adopted a two-pronged geological–archaeological approach. From a geological perspective we have used existing biostratigraphical microfossil data from the Mesozoic succession that characterize the different rock formations in Britain (e.g. Barnard, 1950; Bate, 1964, 1965, 1967, 2009; Bate and Coleman, 1975; Horton and Coleman, 1977; Lord, 1978; Neale, 1978; Coleman, 1981; Hart et al., 1981, 1989; Shipp and Murray, 1981; Copestake and Johnson, 1981, 1989; Morris and Coleman, 1989; Shipp, 1989; Wakefield, 1994, 2009; Boomer and Ainsworth, 2009; Slipper, 2009; Wilkinson and Whatley, 2009; Wilkinson, 2011a,b). In tandem, we have undertaken extensive new analyses of the microfossil signature of the Pleistocene till at Burrough Hill (Table 1). From an archaeological perspective we have analyzed the microfossil content of late Iron Age clay layers for the stone rampart at the main SE entrance to the hill fort, from the recessed room at the entrance, and from the linings of storage pits within the fort (Table 1, Fig. 2, trenches 4–6); we have also disaggregated four mid to late Iron Age potsherds as a pilot study to assess their microfossil content.

##### 4.1. Field sampling for Pleistocene till and clay-based construction materials at Burrough Hill

Sixteen samples of glacial clay were collected by hand auger from five locations east of the hill fort where deposits of the Pleistocene Oadby Till Member are extensive (Fig. 1). The range of samples was targeted to ensure a good representation of the lithological and microfossil components of the till. Samples were

checked in the field for the distinctive blue-grey tint of the Oadby Till and for its characteristic Jurassic and Cretaceous rock inclusions and macrofossils. The uppermost part of the till is affected by soil and weathering, thus samples were taken to a depth of 1.2 m in auger holes. About sixteen samples were collected, each weighing 0.5 kg, of which eleven were selected for microfossil analysis (Table 1).

Archaeological fieldwork focused on clay samples from the rampart of the main SE entrance to the hill fort (Fig. 2, trench 4), from the floor of the recessed room at the main entrance (Fig. 2, trench 4), and from clay linings of storage pits within the fort (Fig. 2, trenches 5 and 6). Sixteen samples of building materials in archaeological contexts have been analyzed for microfossils, with approximately 0.5–1 kg of clay acquired for each (Table 1).

##### 4.2. Laboratory processing of clay samples from the till and hill fort

Clay samples from the till and hill fort were processed through sieves using warm water: sieve meshes of 63, 125, 250, 500 and 1000  $\mu\text{m}$  were used. Samples were oven dried (at 50 °C) overnight and then picked for microfossils using a binocular microscope. The majority of foraminifera were recovered from sieve fractions 63  $\mu\text{m}$  and 125  $\mu\text{m}$  and the ostracods from 125  $\mu\text{m}$  to 250  $\mu\text{m}$ . Key microfossils were mounted on aluminium stubs, gold-coated and imaged by scanning electron microscopy using a Hitachi S-3600N at Leicester University.

##### 4.3. Mechanical and chemical disaggregation of pottery

Using a process discussed by Tasker et al. (2011) for the disaggregation of chalks, four small samples of late Iron Age potsherds were broken into cm-sized pieces and dried in an oven, then soaked in a supersaturated solution of Glauber's Salt (sodium sulphate decahydrate,  $\text{NaSO}_4 \cdot 10 \text{H}_2\text{O}$ ) at 25–30 °C for 2–3 h. After soaking, the solution was decanted off, before the sample was placed in a freezer overnight and thawed out the next day, with this process being repeated if necessary to disaggregate the potsherd. The rapid chilling of the solution encourages high nucleation with small crystal growth of sodium sulphate decahydrate, and this is

**Table 1**

Source of clay materials from the glacial till immediately adjacent to the hill fort at Burrough Hill (samples 1 through 14) and from archaeological contexts within the hill fort (see also Figs. 4 and 5). Sample residues and microfossil assemblages are housed in the collections of the British Geological Survey, Keyworth, Nottingham. The prefix for all grid references is SK.

| Informal field sample identifier | Provenance at site   | Sample type  |
|----------------------------------|--|--|
| <b>Glacial till samples</b>      |  |  |
| 1                                | Grid reference: 76310, 11797<br>(1 m depth)                  | Geological – Oadby Till (recovered by auger in 2011)                                     |
| 2                                | Grid reference: 76310, 11797<br>(1.10 m depth)               | Geological – Oadby Till (recovered by auger in 2011)                                     |
| 3                                | Grid reference: 76310, 11797 (1.20 m depth)                  | Geological – Oadby Till (recovered by auger in 2011)                                     |
| 4                                | Grid reference: 76345, 11792<br>(50 cm depth)                | Geological – Oadby Till (recovered by auger in 2011)                                     |
| 5                                | Grid reference: 76345, 11792<br>(55 cm depth)                | Geological – Oadby Till (recovered by auger in 2011)                                     |
| 6                                | Grid reference: 76345, 11792<br>(60 cm depth)                | Geological – Oadby Till (recovered by auger in 2011)                                     |
| 7                                | Grid reference: 76345, 11792<br>(65 cm depth)                | Geological – Oadby Till (recovered by auger in 2011)                                     |
| 9                                | Grid reference: 76345, 11792<br>(75–80 cm depth)             | Geological – Oadby Till (recovered by auger in 2011)                                     |
| 11                               | Grid reference: 76588, 11514<br>(50 cm depth)                | Geological – Oadby Till (recovered by auger in 2011)                                     |
| 13                               | Grid reference: 76588, 11514<br>(60 cm depth)                | Geological – Oadby Till (recovered by auger in 2011)                                     |
| 14                               | Grid reference: 76312, 11795<br>(1 m depth)                  | Geological – Oadby Till (recovered by auger in 2011)                                     |
| <b>Archaeological samples</b>    |  |  |
| EY1a                             | Grid reference: 76167.239/11845.958<br>(55 cm depth, area 1) | Archaeological – clay from the boundary wall (recovered in 2011 excavation, trench 4)    |
| EY2a                             | Grid reference: 76167.239/11845.958<br>(55 cm depth, area 1) | Archaeological – clay from the boundary wall (recovered in 2011 excavation, trench 4)    |
| EY3a                             | Grid reference: 76167.239/11845.958<br>(55 cm depth, area 1) | Archaeological – clay from the boundary wall (recovered in 2011 excavation, trench 4)    |
| EY4a                             | Grid reference: 76167.239/11845.958<br>(55 cm depth, area 1) | Archaeological – clay from the boundary wall (recovered in 2011 excavation, trench 4)    |
| EY5a                             | Grid reference: 76167.239/11845.958<br>(55 cm depth, area 1) | Archaeological – clay from the boundary wall (recovered in 2011 excavation, trench 4)    |
| EY6a                             | Grid reference: 76167.239/11845.958<br>(55 cm depth, area 1) | Archaeological – clay from the boundary wall (recovered in 2011 excavation, trench 4)    |
| EY7a                             | Grid reference: 76167.291/11846.703<br>(70 cm depth, area 3) | Archaeological – clay from the boundary wall (recovered in 2011 excavation, trench 4)    |
| EY8a                             | Grid reference: 76167.291/11846.703<br>(70 cm depth, area 3) | Archaeological – clay from the boundary wall (recovered in 2011 excavation, trench 4)    |
| EY9a                             | Grid reference: 76167.291/11846.703<br>(70 cm depth, area 3) | Archaeological – clay from the boundary wall (recovered in 2011 excavation, trench 4)    |
| EY10a                            | Grid reference: 76165.198/11854.779                          | Archaeological – floor of the entrance chamber (recovered in 2011 excavation, trench 4)  |
| EY10b                            | Grid reference: 76165.198/11854.779                          | Archaeological – floor of the entrance chamber (recovered in 2011 excavation)            |
| 5063 5004                        | Grid reference: 76134. 676/11893.156                         | Archaeological – clay lining of storage pit (recovered in the 2012 excavation, trench 5) |
| 5040 5041                        | Grid reference 76128.512/11894.008                           | Archaeological – clay lining of storage pit (recovered in the 2012 excavation, trench 5) |
| 5047 5034                        | Grid reference: 76126.405/11880.828                          | Archaeological – clay lining of storage pit (recovered in the 2012 excavation, trench 5) |
| 5053 5008                        | Grid reference: 76133.264/11887.978                          | Archaeological – clay lining of storage pit (recovered in the 2012 excavation, trench 5) |
| 6041                             | Grid reference: 76002.983/11973.775                          | Archaeological – clay lining of storage pit (recovered in the 2012 excavation, trench 6) |

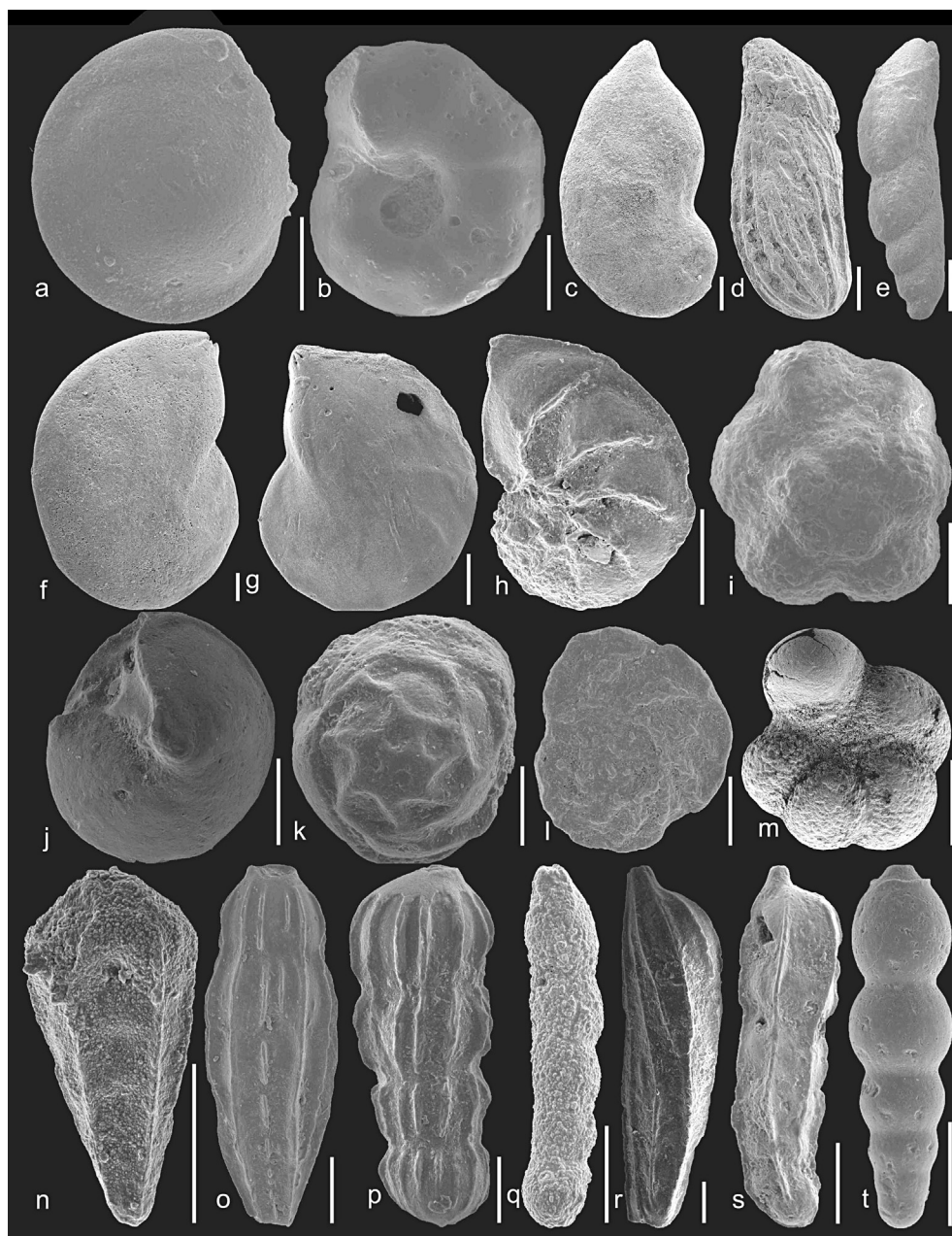
designed to break the potsherd apart without damaging the microfossils. The resulting disaggregated residues were then processed using standard microfossil techniques (see Section 4.1), and then picked for ostracods and foraminifera. The microfossil yield is low from the small fragments of pottery, but can be decisive in identifying the provenance of the raw clay materials.

## 5. Microfossil signature of the Oadby Till Member

Over ninety microfossil species have been identified from the Oadby Till Member, including both ostracods and foraminifera (Supplementary Tables 2 and 3, Figs. 6, 7). Fossils also include echinoid spines, bivalve fragments, gastropods, and calcispheres. Lithological components incorporated into the till include ooids and small fragments of coal. The microfossil assemblages signal derivation from several biostratigraphical horizons and lithostratigraphical units within the Mesozoic succession of England, including those of Jurassic and Cretaceous age (Figs. 6–8). The

dominant element of assemblages is Lower Jurassic and suggests a local source. These are also the best-preserved (and probably least glacially transported) element of the microfossil assemblage. Lower Jurassic foraminifera and ostracods signal a likely primary source from the Dyrham and Whitby Mudstone formations (Fig. 1) that outcrop in the immediate vicinity of the hill. There are less numerous assemblages of Middle and Upper Jurassic foraminifera and ostracods. The Middle Jurassic microfossils may have been derived from the Lincolnshire Limestone Formation and the Blisworth Formation (Morris and Coleman, 1989; Bate, 1978, 2009). Upper Jurassic microfossils include those from the Kimmeridge Clay Formation, although represented by only a few microfossils (Shipp and Murray, 1981; Shipp, 1989; Wilkinson and Whatley, 2009). The Cretaceous microfossils are from the White Chalk Subgroup of the Chalk Group and are typical of the Coniacian to Campanian chalks of southern and eastern England (Hart et al., 1981, 1989; Slipper, 2009; Wilkinson, 2011a). The presence of the calcisphere *Pithonella sphaerica* in the till reinforces the Cretaceous





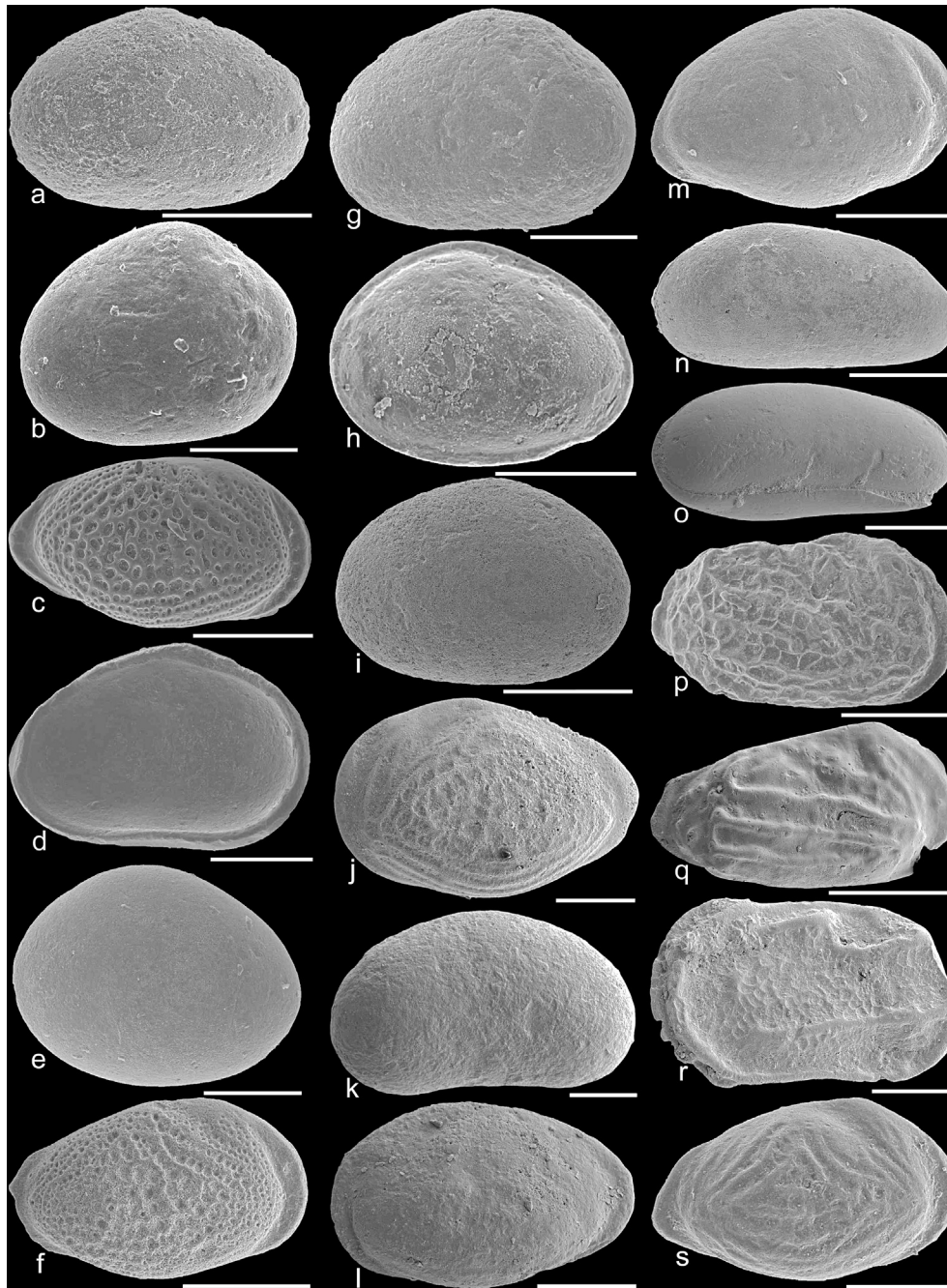
**Fig. 6.** SEM photomicrographs of selected foraminifer species from the Oadby Till (a, b, d, e, g–l, n–t), and from clay materials in archaeological settings (c, f, m) at Burrough Hill. Preservation of the microfossils from both contexts is excellent. Also indicated are the stratigraphical ranges of the foraminifera (see Fig. 6). For sample localities refer to Table 1. Scale bar: 200  $\mu$ m. **a.** *Lenticulina muensteri acutiangulata*, sample 2, lower Pliensbachian to Oxfordian; **b.** *Gavelinella pertusa*, sample 11, Coniacian to Maastrichtian; **c.** *Lenticulina varians*, sample EY4a, Rhaetian (Triassic) to Oxfordian; **d.** *Vaginulina/Citharina clathrata*, sample 6, Toarcian to Aalenian; **e.** *Dentalina mucronata*, sample 14, Bathonian; **f.** *Lenticulina muensteri muensteri*, sample EY3a, upper Sinemurian to upper Toarcian; **g.** *Lenticulina muensteri*, sample 14, Callovian to Portlandian; **h.** *Lenticulina quenstedti*, sample 14, Bajocian to Callovian; **i.** *Trochammina canningensis*, sample 11, Hettangian to Kimmeridgian; **j.** *Globorotalites micheliniana*, sample 3, Turonian to Campanian; **k.** *Reinholdella macfadyeni*, sample 2, upper Pliensbachian to Toarcian; **l.** *Stensioina exsculpta exsculpta*, sample 2, mid Coniacian to Santonian; **m.** *Hedbergella brittonensis*, sample EY10b, Cenomanian to Santonian; **n.** *Lingulina tenera tenera*, sample 6, Rhaetian (Triassic) to Toarcian; **o.** *Lingulina tenera pupa*, sample 3, Hettangian to upper Toarcian; **p.** *Marginulina prima interrupta*, sample 2, upper Sinemurian to lower Toarcian; **q.** *Dentalina pseudocommunis*, sample 6, upper Jurassic; **r.** *Dentalina matutina*, sample 1, lower Sinemurian to upper Pliensbachian; **s.** *Marginulina prima rugosa*, sample 9, lower Sinemurian to earliest Toarcian; **t.** *Pseudonodosaria vulgata*, sample 7, Hettangian to upper Sinemurian.

signature: although this is a long ranging species throughout the Upper Cretaceous, it is present in flood abundance at some horizons (Wilkinson, 2011b).

Although there is a consistent signal of biostratigraphically mixed Mesozoic assemblages across all of the samples, abundance and overall species content vary. This variation is also reflected in the small lithic fragments present within the samples and indicates that the till is locally quite heterogeneous. Thus, locally sourced

iron-rich ooids of the Marlstone Rock Formation are common in the till, while those of the Lincolnshire Limestone Formation, whose crop lies some 12 km to the east of Burrough Hill, are more sporadic in their occurrence. The biostratigraphically and lithologically heterogeneous nature of the till reflects the various bedrock lithologies incorporated as the Anglian ice sheet expanded westwards from the North Sea into the East Midlands. The till also incorporates a taphonomic signature of this transport with





**Fig. 7.** SEM photomicrographs of selected ostracod species from the Oadby Till (a–i, m, p, s), and from clay materials from archaeological settings (j–l, n, o, q, r) at Burrough Hill. Preservation of the microfossils from both contexts is excellent. Also indicated are the stratigraphical ranges of the ostracods (see Fig. 6). For sample localities refer to Table 1. Scale bar: 200  $\mu$ m. **a.** *Ogmoconchella aequalis*, sample 1, Lower Pliensbachian; **b.** *Ogmoconcha hagenowi*, sample 1, Late Hettangian to early Sinemurian; **c.** *Ektyphocythere retia*, sample 3, Lower Sinemurian; **d.** *Ogmoconchella dancia*, sample 7, Early Sinemurian to early Pliensbachian; **e.** *Ogmoconchella eocontractula*, sample 1, Upper Sinemurian to lower Pliensbachian; **f.** *Praeschuleridea pseudokinkelinella*, sample 4, Lower Toarcian; **g.** *Ogmoconchella adenticulata*, sample 1, Upper Pliensbachian; **h.** *Ogmoconcha convexa*, sample 2, Late Pliensbachian and early Toarcian; **i.** *Ogmoconcha contractula*, sample 13, Upper Pliensbachian; **j.** *Ektyphocythere intrepida*, sample EY10a, lower Toarcian; **k.** *Bardiacypris triangularis*, sample EY3a, Lower Toarcian to upper Toarcian; **l.** *Praeschuleridea subtrigona*, sample EY5a, Bajocian to Bathonian; **m.** *Glyptocythere polita*, sample 1, Bajocian; **n.** *Alicenula pulmo*, sample EY1a, Upper Bajocian; **o.** *Alicenula incurva*, sample EY5a, Upper Bathonian; **p.** *Fuhrbergiella (Praefuhrbergiella) horrida horrida*, sample 11, Bajocian; **q.** *Hechticythere serpentina*, sample EY4a, Upper Kimmeridgian to Portlandian; **r.** *Cytherelloidea hindei*, sample EY6a, middle Cenomanian to late Campanian; **s.** *Ektyphocythere sinemuriana*, sample 1, Late Sinemurian.

microfossils from the local Lower Jurassic being most abundant, whilst those from more distant rock formations, especially the Chalk Group, are rare.

## 6. Microfossil signature of clay samples from the hill fort

Clay samples from the layers in the stone rampart at the main SE entrance to the hill fort (trench 4) contain a rich assemblage of both

foraminifer and ostracod species (Supplementary Tables 4 and 5). Certain species such as the foraminifer *Lenticulina varians* and the ostracod *Ogmoconcha adenticulata* are particularly abundant and present in nearly all samples, whereas others are rare and present in only one sample, a variation that is also noted for the till. The 90 species that have been identified from the wall-linings indicate a number of biostratigraphic horizons from the Lower Jurassic through to the Upper Cretaceous. In addition to characteristic

| PERIOD                          | ABSOLUTE AGE (Ma) | AGE/STAGE    | LITHOSTRATIGRAPHY (FORMATIONS) |                         |
|---------------------------------|-------------------|--------------|--------------------------------|-------------------------|
| LATE CRETACEOUS                 | 65.5              |              |                                |                         |
|                                 | 70.6              |              | Southern Chalk Province        | Northern Chalk Province |
|                                 |                   | CAMPANIAN    | Portsmouth Chalk               | Rowe Chalk              |
|                                 |                   |              | Culver Chalk                   | Flamborough Chalk       |
|                                 | 83.5              |              | Newhaven Chalk                 |                         |
|                                 | 85.8              | SANTONIAN    | Seaford Chalk                  | Burnham Chalk           |
|                                 |                   | CONIACIAN    | Lewes Nodular Chalk            |                         |
|                                 | 88.6              | TURONIAN     | New Pit Chalk                  | WeltonChalk             |
|                                 | 93.6              |              | Holywell Nodular Chalk         | FerribyChalk            |
|                                 |                   |              | Zig Zag Chalk                  |                         |
|                                 |                   | CENOMANIAN   | West Melbury Marly             |                         |
|                                 | 99.6              |              |                                |                         |
| 145.5 EARLY CRETACEOUS: OMITTED |                   |              |                                |                         |
| LATE JURASSIC                   |                   | TITHONIAN    | Kimmeridge Clay                |                         |
|                                 | 150.8             | KIMMERIDGIAN |                                |                         |
|                                 | 155.6             | OXFORDIAN    | Oxford Clay                    |                         |
| 161.2                           |                   |              |                                |                         |
| MID JURASSIC                    |                   | CALLOVIAN    | Kellaways                      |                         |
|                                 |                   | BATHONIAN    | Cornbrash                      |                         |
|                                 | 164.7             |              | Blisworth Clay                 |                         |
|                                 |                   |              | Blisworth Limestone            |                         |
|                                 |                   |              | Rutland                        |                         |
|                                 | 167.7             |              |                                |                         |
|                                 |                   | BAJOCIAN     | Lincolnshire Limestone         |                         |
|                                 | 171.6             | AALENIAN     | Grantham                       |                         |
|                                 |                   |              | Northampton Sand               |                         |
|                                 | 175.6             | TOARCIAN     | Whitby Mudstone                |                         |
| EARLY JURASSIC                  | 183.0             | PLIENSACHIAN | Marlstone Rock                 |                         |
|                                 |                   |              | Dyrham                         |                         |
|                                 |                   |              | Charmouth Mudstone             | Scunthorpe Mudstone     |
|                                 | 189.6             | SINEMURIAN   |                                |                         |
|                                 | 196.5             | HETTANGIAN   | Blue Lias                      |                         |
|                                 | 199.6             | RHAETIAN     |                                |                         |
| LATE TRIASSIC                   |                   |              |                                |                         |

**Fig. 8.** Stratigraphic provenance of microfossils recovered from the Oadby Till Member and clay samples from archaeological settings within the context of the hill fort at Burrough Hill (stratigraphic level of fossil materials indicated by the bars to the right of the stratigraphical column). Chalk Group Stratigraphy for the Southern Province is after [Bristow et al. \(1997\)](#) and that for the Northern Province is after [Wood and Smith \(1978\)](#), unified by [Rawson et al. \(2001\)](#) and [Hopson \(2005\)](#). The stratigraphy of the Jurassic is discussed by [Cox et al. \(1999\)](#), [Brenchley and Rawson \(2006\)](#) and [Barron et al. \(2012\)](#).

microfossils, the samples from the clay lining of the main entrance wall also contain a number of lithic fragments between 0.1 and 3.5 cm diameter. These include fragments of chalk, coal, ooids and fragments of rock from the Dyrham, Marlstone Rock, and Lincolnshire Limestone formations. These fragments occur in all of the

clays sampled from the wall, and in addition flint fragments are present in one sample.

Clay materials analyzed from the floor of the recessed room at the main entrance (trench 4) also yield biostratigraphic ages from the Jurassic and Upper Cretaceous and, with one exception that

yielded no microfossils, this is replicated by four clay linings examined from the storage pits in trenches 5 and 6 (for localities see Table 1; see also Supplementary Tables 4 and 5).

### 6.1. Interpretation

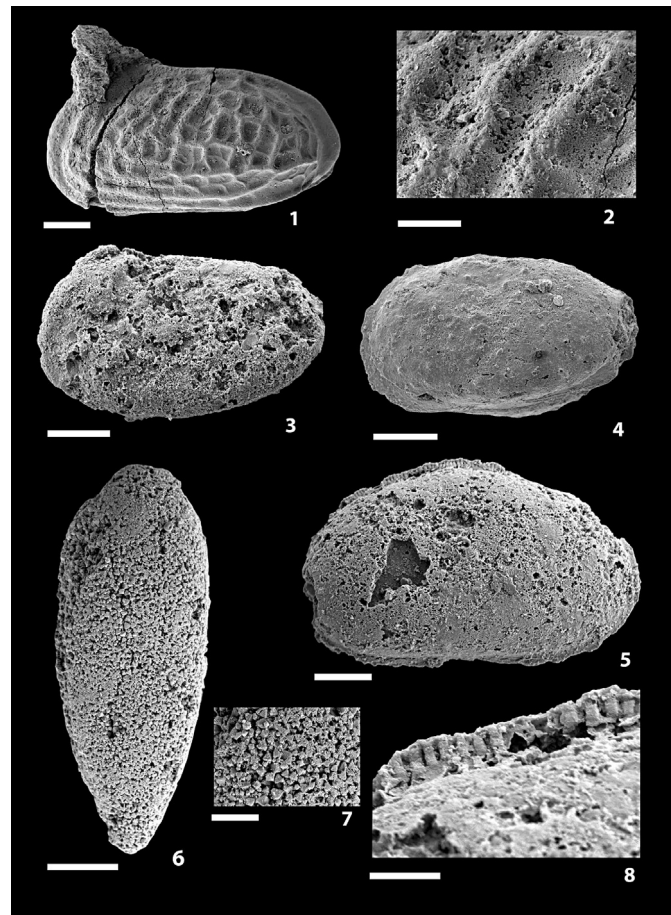
The biostratigraphic signatures of the Oadby Till Member and the clay linings from archaeological settings within the hill fort demonstrate a common pattern. Both the fossil species and age constraints (Jurassic and Cretaceous) are the same for the hill fort and the till. Fossils that dominate assemblages within the Oadby Till Member include the ostracods *Ogmoconchella aspinata*, *O. danica*, *O. adenticulata*, *O. aspinata*, *Ogmoconcha contractula*, *O. hagenowi*, *O. convexa*, *Ektypocythere retia*, *Glyptocythere penni*, *G. polita* and *Praeschuleridea pseudokinkelinella*; and the foraminifera *Lenticulina muensteri*, *Lingulina tenera*, *Dentalina matutina*, *Marginulina prima prima*, *Reinholdella macfadyeni*, *Nodosaria hortensis* and *Marginulina prima rugosa*; and the calcisphere *Pithonella sphaerica*. These taxa and the stratigraphically mixed assemblages are also abundant within the clay materials sourced within the hill fort, as is the commonality of lithic fragments, providing firm evidence that construction materials were sourced from the local till.

### 7. Microfossil signature of mid to late Iron Age potsherds

As a pilot study, a small number of microfossils have been extracted by disaggregation of three mid to late Iron Age scored ware potsherds sourced from trench 3, which lies to the immediate east of the main entrance to the hill fort (Fig. 2), and one from modern topsoil within the hill fort (collected in 2013). Thin sections of the potsherds reveal the presence of nodosariid benthonic foraminifera such as *Lenticulina*, *Dentalina* and possible *Marginulina*, although these cannot be identified to species level. Similarly, ostracods are observed in the thin sections. Although rare and partly calcined by the firing process, several ostracod valves and carapaces have been extracted from the potsherds, including *Ogmoconchella* sp. cf. *O. danica* or possibly *Ogmoconcha adenticulata* of Sinemurian–Pliensbachian (Early Jurassic) age, and *Glyptocythere scitula* of Middle Jurassic age, and *Kinkelinella* sp. of Toarcian (Early Jurassic) age (Fig. 9). Preliminary results therefore indicate a mixture of microfossils that are consistent with those found in the Oadby Till Member, and within unfired clay materials used within the hill fort for construction.

### 8. Conclusions

Foraminifera and ostracod microfossils from the Oadby Till Member at Burrough Hill provide a mixture of biostratigraphic ages from the Jurassic and Upper Cretaceous that signal the path of the Anglian ice sheet as it transgressed from the North Sea region into the East Midlands of England, forming the glacial deposits around Burrough Hill. Clay linings from archaeological contexts at Burrough Hill contain a common biostratigraphical signature with the till, and a commonality of lithic fragments of chalk, coal, Dyrham Formation, flint, Marlstone Rock Formation, and Lincolnshire Limestone Formation. Collectively this demonstrates that the local till was used as the main source of clay for construction at Burrough Hill. Microfossil analysis of the till and clay linings at Burrough Hill provides a detailed palaeontological baseline that can be used to assess the provenance of clay used in pottery at the site, and a small pilot study of four Mid to late Iron Age potsherds also suggest a source from the Oadby Till Member. Our analysis demonstrates the power of microfossils to provenance clay materials used for construction and manufactures at an Iron Age site in lowland Britain,



**Fig. 9.** Microfossils recovered from mid to late Iron Age scored ware pottery at Burrough Hill: Ostracods (1–5, 8) and foraminifera (6, 7). Specimens of images 3, 5, 6 are from pottery sample 50, and 4 from pottery sample 41, both recovered from trench 3 (see Fig. 2 for locality); 1 and 2 are from an uncatalogued shell tempered potsherd recovered from a soil profile within the hill fort. 1, 2 – *Glyptocythere scitula*, tectonophor carapace, left lateral view and detail of surface reticulae respectively. 3 – cf. *Glyptocythere* sp., internal cast, left valve, lateral view. 4 – cf. *Kinkelinella* sp., carapace, left lateral view. 5, 6 – cf. *Bolivina* sp., internal cast or denatured test, and close-up of test surface respectively. 7, 8 – *Ogmoconchella* cf. *danica* (or possibly *Ogmoconcha adenticulata*), internal cast of carapace, probable left lateral view and detail of hinge respectively. The specimens of *Glyptocythere* are considered to be of Middle Jurassic age and *Ogmoconchella/Ogmoconcha* is from the Early Jurassic. *Kinkelinella* is particularly common in the Toarcian (Early Jurassic) of the East Midlands, but it also extends into the Bajocian (Middle Jurassic). Scale bars: 2, 8 = 25  $\mu$ m 7 = 50  $\mu$ m 1, 3–6 = 100  $\mu$ m.

when a detailed baseline understanding of the local geology is first established.

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### Appendix A. Supplementary data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.jas.2014.03.028>.



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